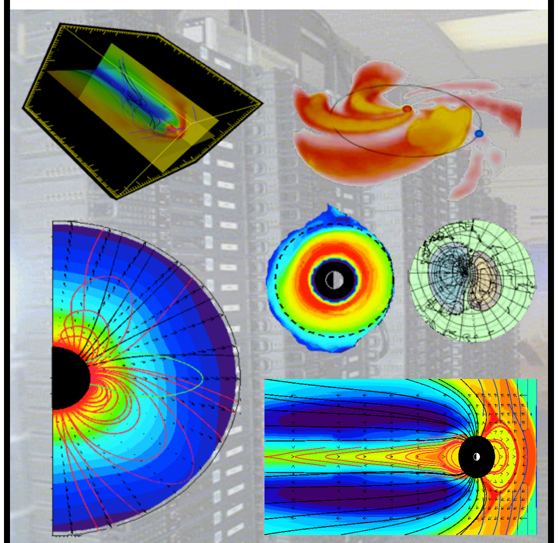
Systematic Assessment of IT Models : TEC/NmF2/hmF2 during 2006 AGU Storm



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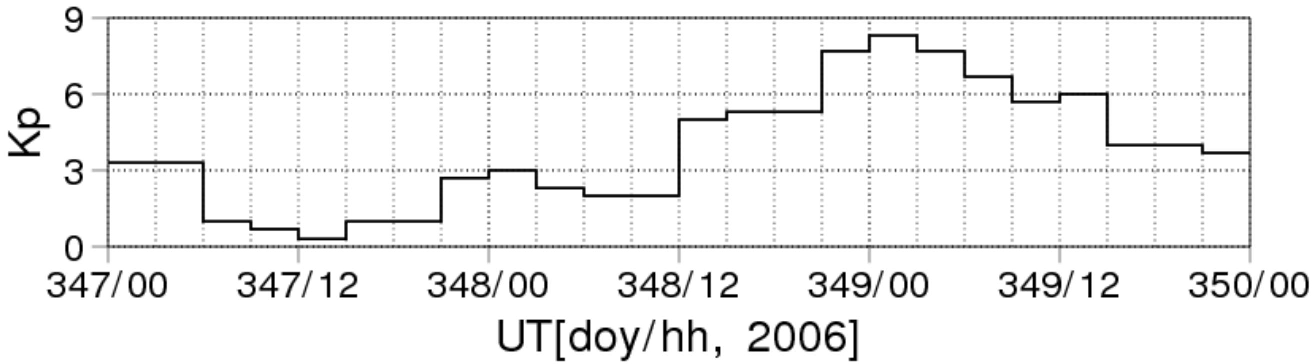
http://ccmc.gsfc.nasa.gov

NASA Goddard Space Flight Center

Setup

- Time interval: E.2006.347-2006.349
  (2006/12/13 00:00 UT - 12/15 23:45 UT)



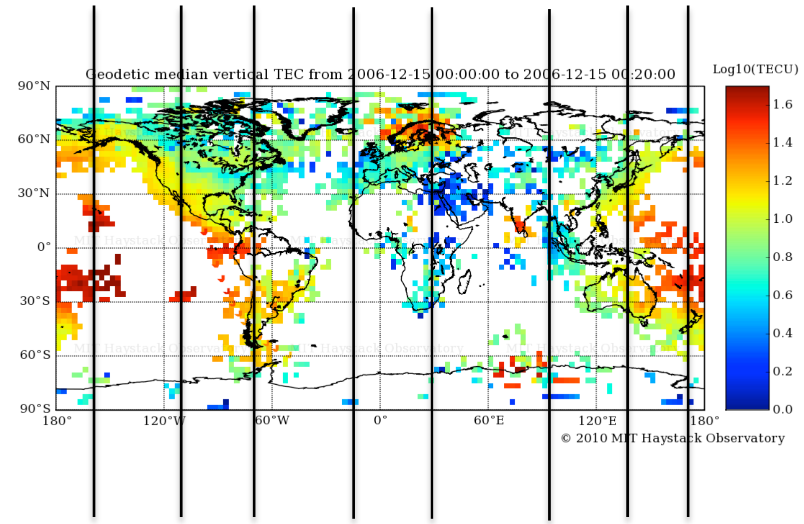
- Physical parameter : global TEC, NmF2, and hmF2

Setup

- Observations :
  - GPS TEC (MIT, JPL, IGS)
  - COSMIC NmF2 and hmF2 (USU)

  - in eight longitude sectors
    : 025-030, 090-095, 140-145, 175-180,
    200-205, 250-255, 285-290, 345-350

  - data bin : 5° lat × 5° lon × 15 min
    36 latitude bins of 5° each from -90 to +90.



Metrics

- RMS Error : $\sqrt{\dfrac{\sum (x_{mod} - x_{obs})^2}{N}}$
- Mean Absolute Percentage Error (MAPE): $\dfrac{\sum \left|(x_{mod} - x_{obs}) / x_{obs}\right|}{N} \times 100$
- Ratio of the maximum change in amplitudes : $\dfrac{(x_{mod})_{\max} - (x_{mod})_{\min}}{(x_{obs})_{\max} - (x_{obs})_{\min}}$
- Ratio of the maximum amplitudes: $\dfrac{(x_{mod})_{\max}}{(x_{obs})_{\max}}$

(length of the time window for ratio calculations = 24 hrs)

Model Setting

	Model Setting ID	
1	1_IRI*	IRI-2007, empirical ionospheric model
2	1_SAMI3_HWM93*	SAMI3 with the neutral wind model HWM93
3	1_USU-IFM*	IFM driven by F10.7, Kp and empirical inputs for the thermosphere parameters
4	1_CTIPE*	CTIPe driven by Weimer electric potential model, 2°×18°, 15 levels in logarithm of pressure
5	1_TIE-GCM*	TIE-GCM1.93 driven by Heelis electric potential model with constant critical co-latitudes
6	2_TIE-GCM	TIE-GCM1.94 driven by Weimer electric potential model with dynamic critical co-latitudes
7	3_TIE-GCM	TIE-GCM1.94 driven by Weimer electric potential model with dynamic critical co-latitudes and with double resolution
8	1_USU-GAIM*	USU-GAIM23 with GPS TEC observations from up to 400 ground stations
9	2_IRI	IRI-2012 using IRI-corr for topside Ne and CCIR F-peak
10	2_CTIPE	CTIPe runs at NOAA/SWPC with Weimer 2005 using 1-minute solar wind and IMF from ACE
11	4_TIE-GCM	TIE-GCM1.94 with Weimer 2005 and SABER/TIDI lower boundary conditions in double resolution
12	5_TIE-GCM	TIE-GCM1.94 driven by AMIE with constant critical cross-over latitudes (fixed at 55 and 70 mlat)
13	1_UAM	Upper Atmosphere Model (UAM), A.A. Namgaladze et al., FAC as external driver
14	2_UAM	UAM with AMIE electric potentials as external drivers
15	3_UAM	UAM with Weimer-2005 (and/or Weimer-96) electric potentials

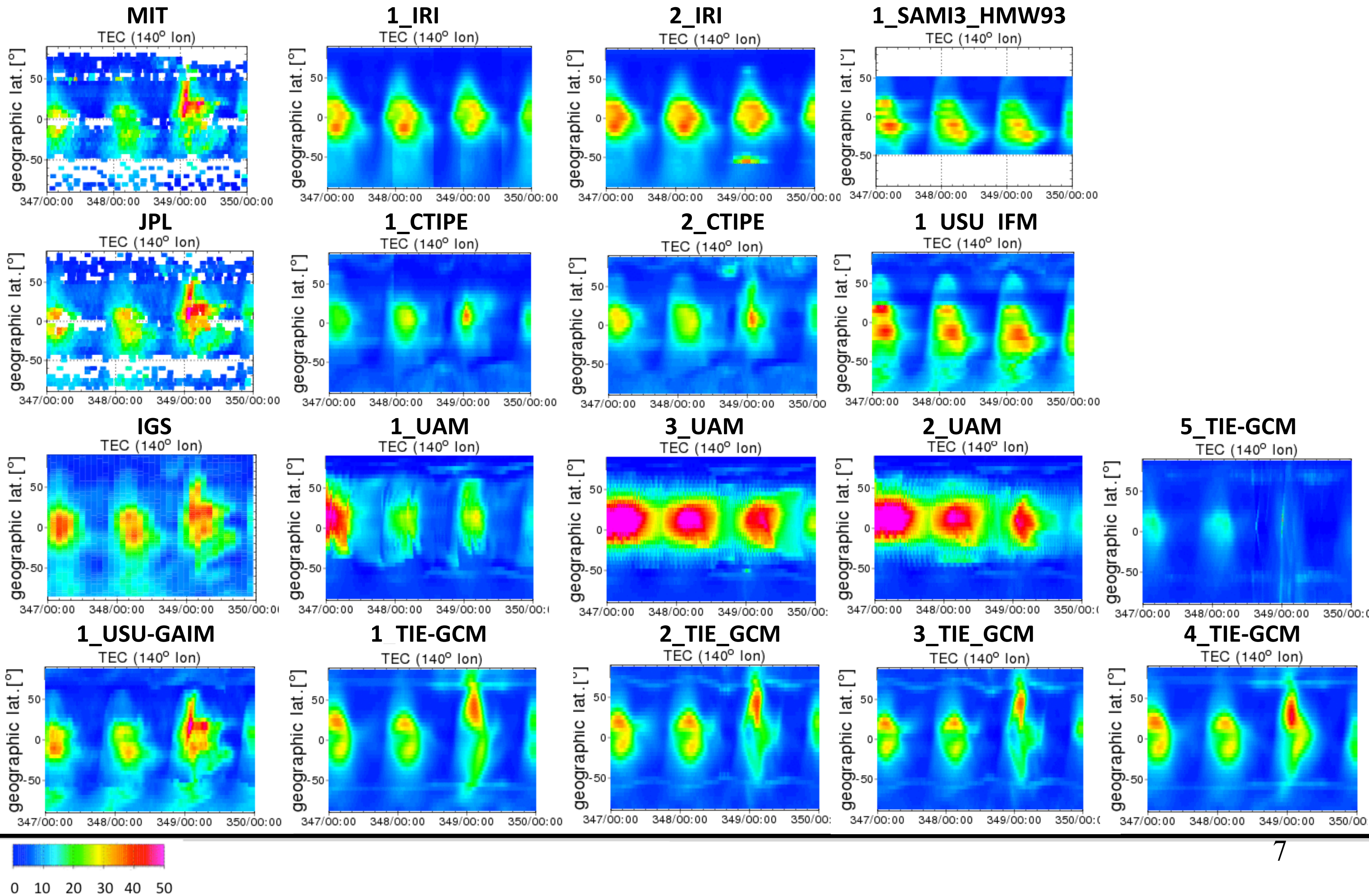
*Runs performed at the CCMC

Model Setting

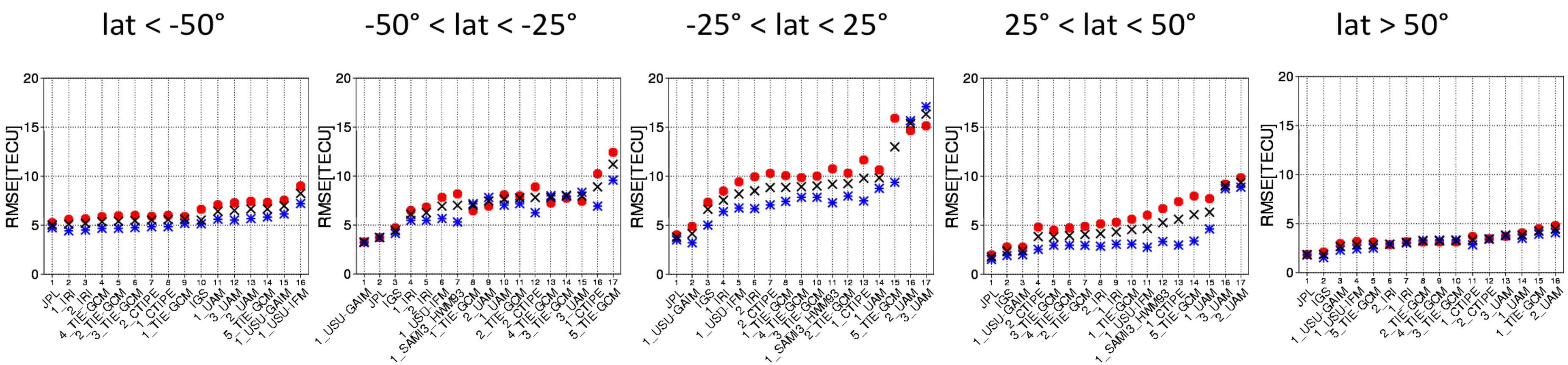
* new submissions for neutral wind, temperature and density

	Model Setting ID	
16	1_HWM07	HWM07 model
17	1_NRLMSISE-00	Original NRLMSISE-00 model
18	2_NRLMSISE-00	Original NRLMSISE-00 model plus yearly corrections to exospheric temperature and density and composition at 120 km, based on annual average ratio of orbit derived densities to MSIS

TEC measurements and modeled values (140°E lon)



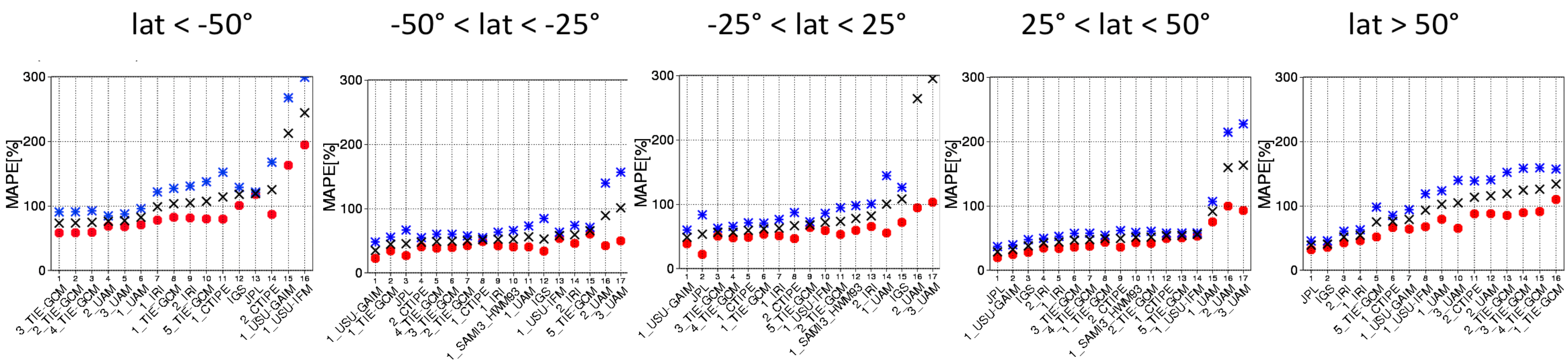
TEC from GPS: RMSE



- the best performing model is located in the extreme left.
- model ranking is arranged by score for 24 hrs (denoted by cross).
- red circle : score for daytime (0600-1800 LT)
- blue eight point asterisk : score for nighttime (1800-0600 LT)

- RMSE during the day > during the night in most cases
- data assimilation model, 1_USU-GAIM ranks at the top except for the southern high latitudes.
- largest value during daytime in the low latitudes.
- no big difference in RMSE between models in high latitudes
- CTIPEs & TIE-GCMs < UAMs & 5_TIE-GCM in low and the northern middle latitudes.

TEC from GPS: MAPE

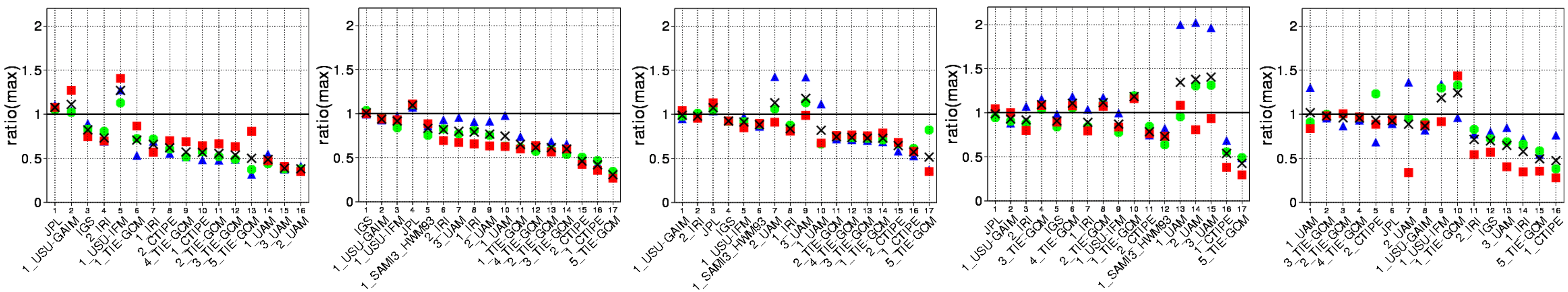


- the best performing model is located in the extreme left.
- model ranking is arranged by score for 24 hrs (denoted by cross)
- red circle: score for daytime (0600-1800 LT)
- blue eight point asterisk : score for nighttime (1800-0600 LT)

- MAPE during the night > during the day
- 1_USU-GAIM ranks at the top in low and middle latitudes.
- IRIs and coupled models rank higher in high latitudes.
- TIE-GCMs < UAMs < CTIPEs in the southern high latitudes
- 5_TIE-GCM & 1_CTIPe < the other coupled model submissions in the northern high latitudes

TEC from GPS: ratio (max)

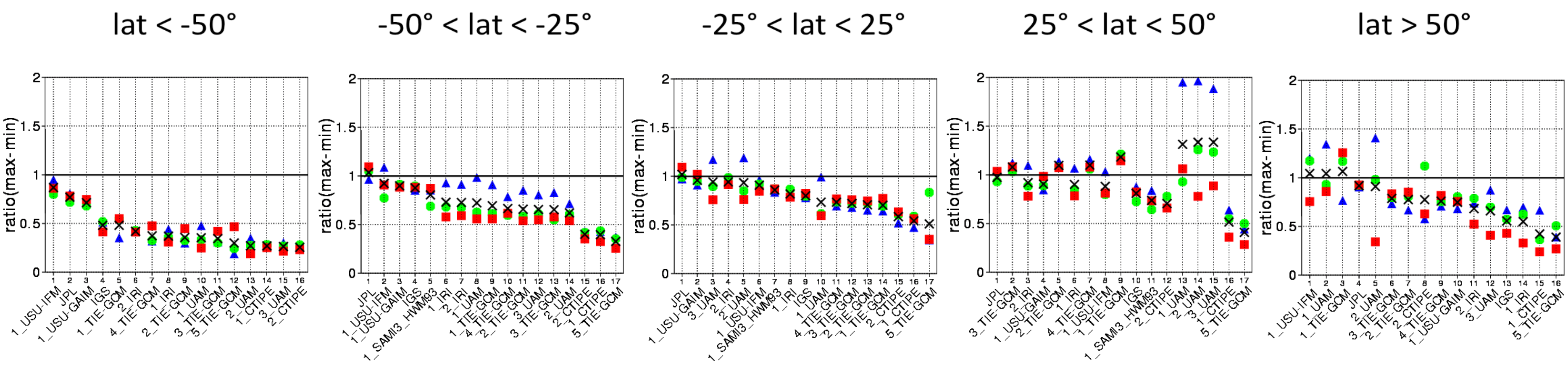
lat < -50°　　-50° < lat < -25°　　-25° < lat < 25°　　25° < lat < 50°　　lat > 50°



- 24-hr time window
- model ranking is arranged by the average ratio of the three day values (denoted by cross)
- blue triangle : ratio of max of the first day (quiet day) of the event (12/13)
- green circle : ratio of the second day (first day of storm) of the event (12/14)
- red square : ratio of the third day of the event (12/15)

- in most cases, ratio(max) < 1 : models do not cover up to GPS altitude.
- JPL > 1, IGS < 1
- 1_USU-GAIM > 1, 1_USU-IFM > 1 in the southern hemisphere
- UAMs >1 in low and the northern middle latitudes

TEC from GPS: ratio (max-min)



- 24-hr time window
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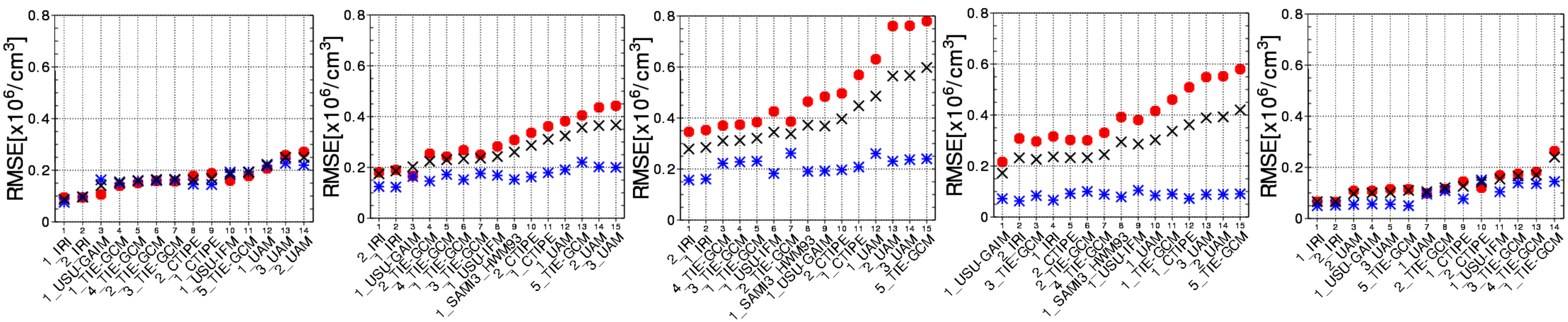
- blue triangle : ratio of max of the first day (quiet day) of the event (12/13)
- green circle : ratio of the second day (first day of storm) of the event (12/14)
- red square : ratio of the third day of the event (12/15)

- in most cases, the models underestimate diurnal variation of TEC.
- JPL ≥ 1, IGS < 1
- UAMs > 1 during quiet time in low and the northern middle latitudes
- 5_TIE-GCM < 0.5

NmF2 from COSMIC: RMSE

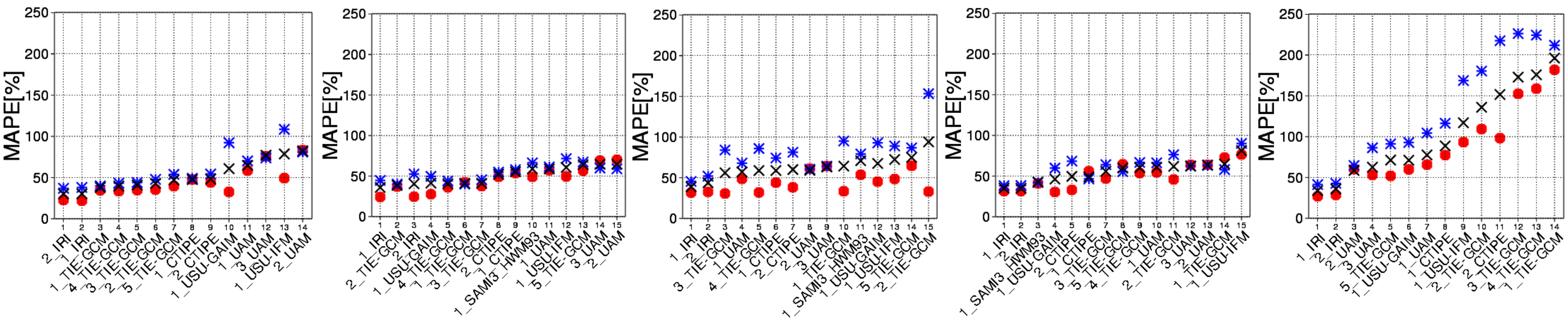
lat < -50°   -50° < lat < -25°   -25° < lat < 25°   25° < lat < 50°   lat > 50°



- larger difference between daytime and nighttime RMSE values in the low and the northern middle latitudes.
- similar scores during the night
- IRIs show lowest RMSE for all latitudes except for the northern middle latitudes.
- UAMs and 5_TIE-GCM have larger RMSE in the low and the northern middle latitudes during the day.

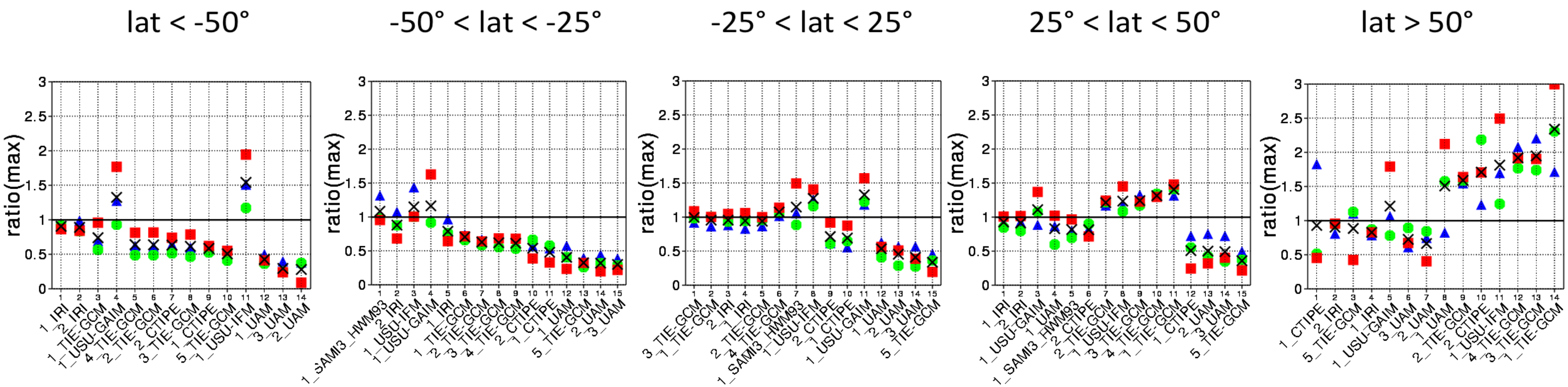
NmF2 from COSMIC: MAPE

lat < -50° | -50° < lat < -25° | -25° < lat < 25° | 25° < lat < 50° | lat > 50°



- all models show worse MAPE in the northern high latitudes than the other latitude.
- MAPE during the night > during the day
- largest MAPE : nighttime in the northern high latitude
- IRIs rank at the top and are followed by physics-based models.
- UAMs < TIE-GCMs and CTIPEs in the northern high latitudes
- UAMs > TIE-GCMs and CTIPEs in the southern high latitudes

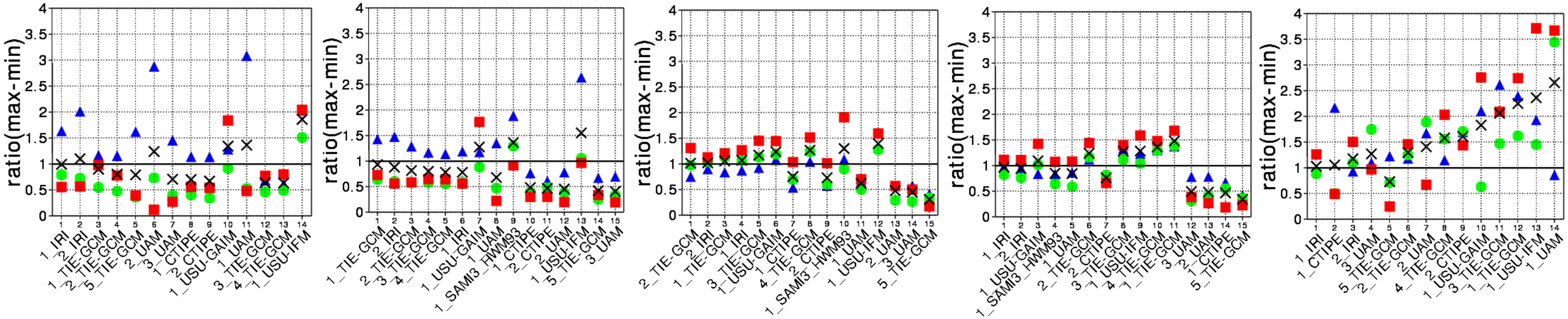
NmF2 from COSMIC: ratio(max)



- physics-based models and IRIs rank at the top based on the average ratio of max of NmF2.
- CTIPEs < 1, UAMs < 1
- 1_USU-GAIM > 1, 1_USU-IFM > 1
- TIE-GCMs : < 1 in the southern hemisphere, > 1 in the northern hemisphere
- TIE-GCMs and CTIPEs show better ratios of max than UAMs and 5_TIE-GCM for most cases except in the northern high latitudes.

NmF2 from COSMIC: ratio(max-min)

lat < -50° | -50° < lat < -25° | -25° < lat < 25° | 25° < lat < 50° | lat > 50°



- physics-based models and IRIs rank at the top based on the average value.
- during the main phase of the storm for most models :

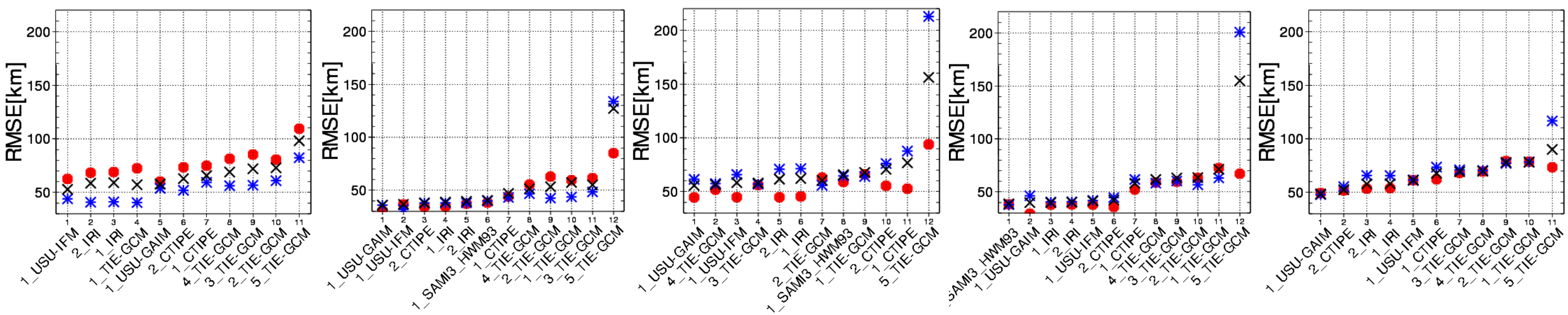
  ratio(max-min) < 1 in the southern hemisphere

  ratio(max-min) > 1 in the northern hemisphere
- during the quiet time in the southern hemisphere for most models:

  ratio(max) < 1 and ratio(max-min) > 1 => $(x_{mod})_{\min} < (x_{obs})_{\min}$

hmF2 from COSMIC: RMSE

lat < -50° | -50° < lat < -25° | -25° < lat < 25° | 25° < lat < 50° | lat > 50°

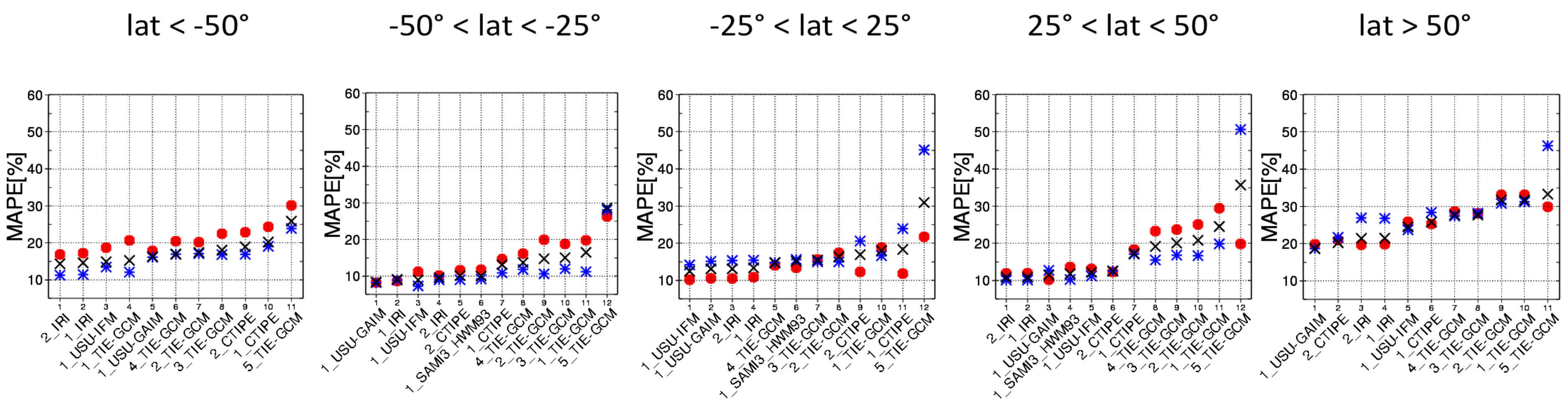


- coupled IT models rank lower than the others
- middle latitude during daytime :

  data assimilation < empirical, ionospheric < coupled IT models
- middle latitude during nighttime :

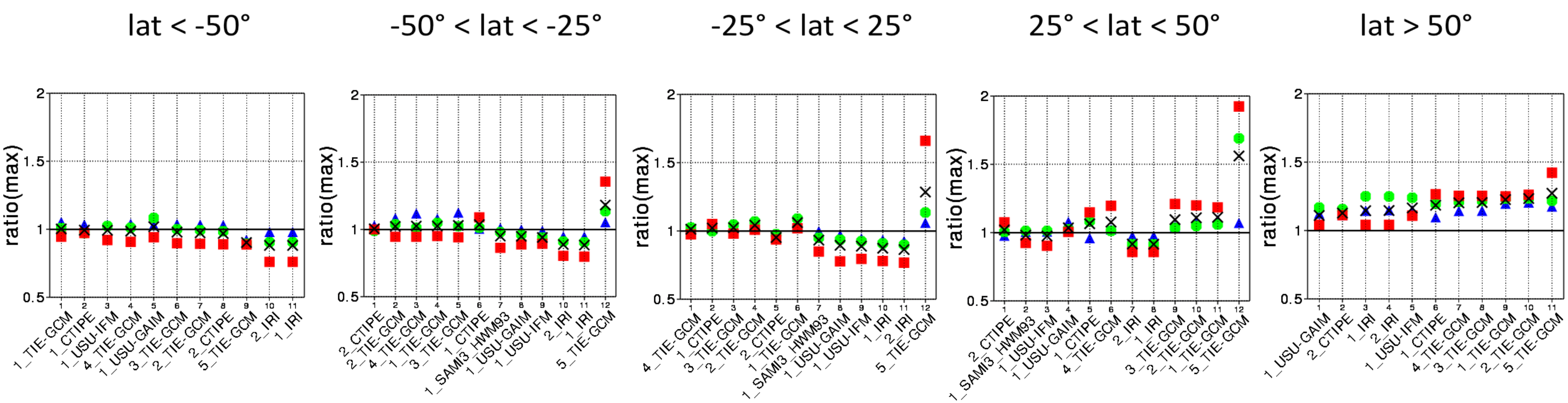
  empirical, ionospheric < data assimilation < coupled IT models
- 5_TIE-GCM > the other TIE-GCMs and CTIPEs

hmF2 from COSMIC: MAPE



- coupled IT models rank lower than the others
- largest MAPE in the high latitudes of the northern hemisphere
- 5_TIE-GCM > the other TIE-GCMs and CTIPEs

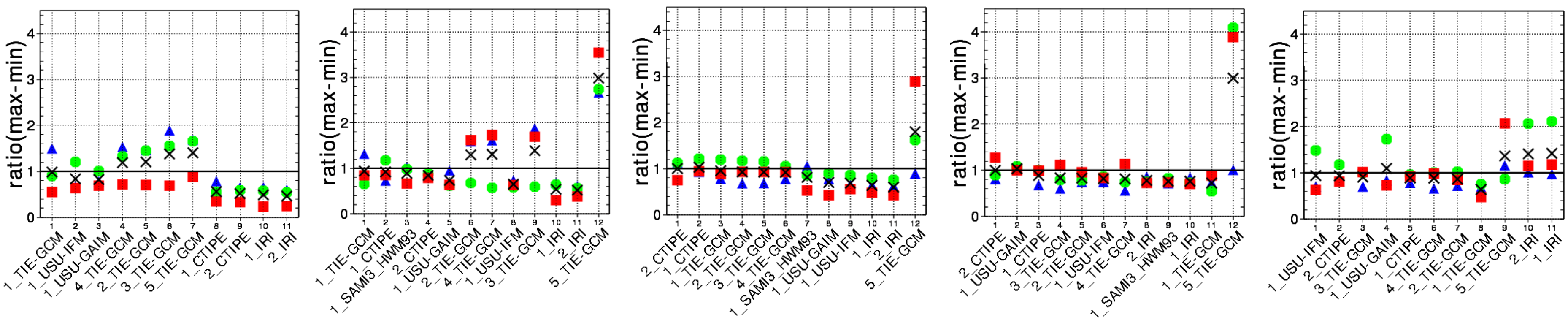
hmF2 from COSMIC: ratio(max)



- physics-based models rank higher than IRIs and 1_USU-GAIM in most cases except in the northern high latitudes.
- models produce similar ratios of max except for 5_TIE-GCM
- during the main phase of the storm:
  - underestimate in the southern high latitudes,
  - overestimate in the northern high latitudes,
  - 5_TIE-GCM shows worse performance than the other TIE-GCMs and CTIPEs.

hmF2 from COSMIC: ratio(max-min)

lat < -50° | -50° < lat < -25° | -25° < lat < 25° | 25° < lat < 50° | lat > 50°



- during the quiet time:
  - IRIs rank higher in the northern high latitudes,
  - 1_USU-GAIM and physics-based ionospheric models rank at the top in the rest of latitudes.

- during the main phase of the storm:
  - coupled models rank higher than the others,
  - 5_TIE-GCM shows worse performance than the other TIE-GCMs and CTIPEs.

Summary

- MIT ≤ JPL ~ IGS,   IGS_max ≤ MIT_max and/or JPL_max

- model performance depends on

  - latitude
  - local time
  - metrics selection
  - high latitude drivers

- paper including all model results submitted so far will be submitted to Space Weather.

* poster : SOLA-05 (Tuesday, 06/26)